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CLASSIFICATION CHANGE
To UNCLASSIFIED
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Changed by L. Shirley Date 12/31/72
Classified Document Master Control Station, NASA
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GRUMMAN AIRCRAFT ENGINEERING CORPORATION
Bethpage, L. I., N. Y.

Page: Title and 74

This document supersedes Specification No. LSP-310-405, dated 8-29-63.

SPECIFICATION

No. LSP-310-405A Date: 2-24-64

TANK ASSEMBLIES, POSITIVE EXPULSION, PROPELLANT

REACTION CONTROL SUBSYSTEM

DESIGN CONTROL SPECIFICATION FOR [U]

Contract No. NAS 9-1100

Exhibit E; para. 4.2 Line Item No. 10

Document Type I Primary No. 509

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SPECIFICATION

Grumman

Spec. No. LSP-310-405A

Date: 2-24-64

Page: A

Rev.	Date	REVISION DESCRIPTION
A	2-24-64	This revision reflects the changes agreed upon during subcontract negotiations with the vendor. The revised paragraphs are marked with a line in the right hand margin of the page.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TANK ASSEMBLIES, POSITIVE EXPULSION, PROPELLANT

REACTION CONTROL SUBSYSTEM

DESIGN CONTROL SPECIFICATION FOR

1 SCOPE

1.1 Scope. - This specification establishes design, fabrication, performance and quality assurance requirements for the Positive Expulsion Propellant Tanks for the Reaction Control Subsystem to be used in the Lunar Excursion Module (LEM), of the Apollo Spacecraft.

1.2 Classification. - The Positive Expulsion Propellant Tanks shall consist of the following:

(a) Fuel Tank Assembly

(b) Oxidizer Tank Assembly

2 APPLICABLE DOCUMENTS

2.1 Government Documents. - The following Government documents of issue in effect on 14 January 1963, or as otherwise specified, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-C-5541	Chemical Films for Aluminum and Aluminum Alloys
MIL-C-45662A	Calibration Requirement System

2.1 (Continued)

MIL-I-6866A	Inspection, Penetrant Method of
MIL-T-5021C	Tests, Aircraft and Missile Welding Operations, Qualifications
MIL-I-25135C	Inspection, Material Penetrant
MIL-T-9046C	Titanium and Titanium Alloys Sheet, Strip and Plate
MIL-T-9047C	Titanium and Titanium Alloys, Bars, Forging and Forging Stock
MIL-A-18455B	Argon, Technical
MIL-P-26539A	Propellant, Nitrogen Tetroxide
MIL-P-27401B Type 1	Propellant Pressurizing Agent, Nitrogen
MIL-P-27402	Propellant, Hydrazine, Unsymmetrical Dimethylhydrazine (50% N_2H_4 - 50% UDMH)

STANDARDS

<u>Military</u>

MIL-STD-10A	Surface Roughness and Waviness of Lay
MIL-STD-12B	Abbreviations for use on Drawings and in Technical Type Publications
MIL-STD-130B	Identification Marking of U.S. Military Property
MIL-STD-143	Specification and Standards, Order of Precedence for the Selection of

2.1 (Continued)

MIL-STD-453	Military Standard Inspection, Radiographic
MIL-STD-810	Environmental Tests for Aerospace and Ground Equipment

Federal

FED-STD-151a	Metals, Test Methods
Change Notice 4, November 28, 1962	

2.2 Grumman Documents. - The following Grumman documents of date of issue shown form a part of this specification to the extent specified herein:

Specification	Date	Title
LSP-390-001	7-9-63	Bonding, Electrical, General Specification for

Drawings	Date	Title
LSC-310-405	8-29-63	Tank - Propellant - RCS - Expulsion (Specification Control Drawing for)

2.3 Other Documents. - The following documents, issued by the organization indicated and of the date of issue shown, form a part of this specification to the extent specified herein:

Helium Grade A Bulletin 585	U.S. Department of Interior Bulletin 585

2.3 (Continued)

SAE-ARP-598	Society of Automotive Engineers Procedure for the Determination of Particulate Contamination by the Particle Count Method
AMS4951	Titanium Wire, Welding
ASTM-E-112	Estimating the Average Grain Size of Metal

2.4 Availability of Documents. -

2.4.1 Government Documents. - Copies of Government documents may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

2.4.2 Grumman Documents. - Copies of this specification and other applicable Grumman documents may be obtained from LEM Program Data Management, Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York.

2.4.3 Other Documents. - Copies of other documents may be obtained from the appropriate organization listed in 2.3.

3 REQUIREMENTS

3.1 General. - The positive expulsion propellant tanks required per vehicle (two oxidizer and two fuel) are shown schematically in Figure 1.

3.1.1 Tank Assemblies. - Each propellant tank assembly shall be composed of the following subassemblies:

(a) Tank shell subassembly

(b) Positive expulsion device

(c) Tank vent

3.1.1.1 Tank Shell Subassembly. - The tank shell subassembly shall consist of two (2) machined tank end domes plus a central cylindrical section. The three elements shall be machined from forgings of titanium in accordance with 3.8.6.1. The forgings, and the billets they are forged from shall meet the requirements of Table VII and shall in addition be uniform in quality and condition, free from surface and subsurface defects, laps, seams, pipe, slivers, scales, slag, porosity, cracks, hard spots and all other defects which may prevent the tanks from meeting the requirements of this specification. Provisions for attaching helium plumbing to the tank shall be incorporated in the tank shell subassembly.

3.1.1.2 Positive Expulsion Device. - The positive expulsion device shall consist of a multi-ply teflon bladder, a standpipe and a closeout device. Provisions for attaching propellant plumbing to the tank shall be incorporated in the closeout device.

3.1.1.3 Tank Vent. - The tank shall include a vent to facilitate control of fill, ullage and flush procedures. The vent shall consist of a tube within the standpipe that runs from the top of the standpipe through the bend in the pipe outside of the closeout device. The materials used for the vent tube shall be compatable with the materials of the standpipe assembly.

3.2 Propellant Tank Assemblies. -

3.2.1 Oxidizer Tank Assembly. -

3.2.1.1 Fluids. - The oxidizer tank assembly shall be compatible with the following fluids or any mixture thereof, for both continuous and intermittent exposure:

(a) Nitrogen tetroxide (N_2O_4) in accordance with Specification MIL-P-26539 (hereinafter referred to as oxidizer)

3.2.1.1 (Continued)

(b) Bureau of Mines, Grade "A", oil-free commercial helium per U.S. Department of Interior Bulletin 585 (used for system pressurization and leakage tests)

(c) High grade, oil-free commercial nitrogen per MIL-P-27401B, Type 1 (used for system purging and drying)

3.2.1.2 Volume. - The oxidizer tank assembly shall have a combined propellant and ullage volume such that 203.7 lbs. of nitrogen tetroxide at a temperature of 65°F (density 90.45 lbs/cu. ft.) and 25 psig will result in a tank pressure of no more than 130 psia when heated to 100°F.

3.2.1.2.1 Fill Temperature. - The oxidizer will be filled at a controlled temperature of 70°F ± 5°.

3.2.1.3 Configuration. - The oxidizer tank assembly shall not exceed the envelope shown on Specification Control Drawing LSC-310-405. The required ports and mounting shall be in accordance with LSC-310-405.

3.2.2 Fuel Tank Assembly. -

3.2.2.1 Fluids. - The fuel tank assembly shall be compatible with the following fluids or any mixture thereof, for both continuous and intermittent exposure:

(a) Hydrazine/UDMH in accordance with Specification MIL-P-27402 (hereinafter referred to as fuel)

(b) Bureau of Mines, Grade "A", oil-free commercial helium per U.S. Dept. of Interior Bulletin 585 (used for system pressurization and leakage tests)

(c) High grade, oil-free commercial nitrogen per MIL-P-27401B Type 1 (used for system purging and drying)

3.2.2.2 Volume. - The fuel tank assembly shall have a combined propellant and ullage volume such that 103.5 lbs. of Hydrazine/UDMH at a temperature of 65°F (density - 56.49 lbs/cu. ft.) and 25 psig will result in a tank pressure of no more than 130 psia when heated to 100°F.

3.2.2.2.1 Fill Temperature. - The fuel shall be filled at a controlled temperature of 70°F ± 5°F.

3.3 Performance. - The oxidizer and fuel tank assemblies shall meet the requirements specified below when operated within the range of environmental conditions specified in Table I.

3.3.1 Definition. - Thenceforth the term tank assembly shall be used to denote both the oxidizer and fuel tank assemblies, where the conditions apply equally to both. They are referred to singularly as the oxidizer tank assembly or fuel tank assembly where the conditions differ in quality or quantity.

3.3.2 Leakage. -

3.3.2.1 Internal Helium Leakage. - Helium leakage including permeation through the expulsion device into the propellant compartment shall not exceed 2 x 10^{-6} pounds per hour with any pressure differential across the device up to 10 psi, at any temperature between 40° and 100°F.

3.3.2.2 External Helium Leakage. - External helium leakage from the bladder closeout port plus the internal helium leakage (3.3.2.1) shall not exceed 4 x 10^{-6} lbs/hr. at any pressure up to and including 250 psig, at any temperature between 40° and 100°F.

3.3.2.3 Propellant Permeation. - The vendor shall establish the propellant permeation rate (both fuel and oxidizer) for the bladder material selected. At any propellant temperature from 40° to 100°F the permeation rate shall not result in propellant saturation of the helium at maximum ullage conditions in less than 20 days.

3.3.2.4 External Propellant Leakage. - There shall be no propellant leakage from the tank assembly at any pressure up to and including 250 psig, at any temperature between 40° and $100^{\circ}F$.

3.3.3 Pressures. -

3.3.3.1 Nominal Pressure. - The nominal tank pressure shall be 181 ± 4 psig.

3.3.3.2 Maximum Expected Operating Pressure. - Each tank assembly designed for a maximum expected operating pressure (MEOP) of 250 psig.

3.3.3.3 Proof Pressure. - The tank assembly shall be capable of withstanding an internal pressure of 333 psig.

3.3.3.4 Burst Pressure. - The tank assembly shall be capable of withstanding an internal pressure of 375 psig without structural failure.

3.3.3.5 Differential Pressure. - The bladder, standpipe and port design shall be such that neither 25 psig in the propellant compartment with zero psig at the helium inlet, nor 250 psig helium pressure with zero psig at the propellant outlet will cause expulsion device failure or damage.

3.3.4 Pressure Drop. -

3.3.4.1 Propellant Expulsion. - Pressure drop from helium inlet to propellant outlet during a 95% expulsion at the following flow rates shall not exceed two (2) psi.

(a) Fuel: 0.11 to 0.44 pounds per second

(b) Oxidizer: 0.22 to 0.88 pounds per second

3.3.4.2 Propellant Filling. - Complete actuation of the expulsion device for propellant filling shall require a pressure differential of less than one (1) psi.

3.3.5 Expulsion Efficiency. - With the tank assembly positioned in any attitude, it shall be capable of expelling at least 99% of its propellant capacity.

3.3.6 Duty Cycle. - The duty cycle is defined as evacuation, propellant loading and complete expulsion of the propellant by intermittent pulsating flows at the following rates and pulse duration at a working pressure of 181 $\pm$ 4 psig during flow.

(a) Fuel: 0.11 to 0.44 pounds per second, pulse duration 5 seconds to 6 minutes

(b) Oxidizer: 0.22 to 0.88 pounds per second, pulse duration 5 seconds to 6 minutes

3.3.7 Endurance Cycling. - The tank assembly as delivered to Grumman shall be capable of a minimum of 50 cycles of operation as described in 3.3.6 through a propellant temperature range of 40°F to 100°F. Helium pressurant at -20°F in the helium tank shall be utilized in at least 2 cycles of operation. Propellant shall be expelled but the bladder need not be operable after the end of testing. In addition the tank and its closeout devices shall be designed to withstand 3000 pressure cycles as described in 4.3.11.2.

3.3.8 Slosh. - The tank assembly shall withstand a reciprocating motion described in 4.3.7.

3.3.9 Life Requirements. - The tank assembly will be employed in a space vehicle as well as in test stands and test vehicles for ground test. The assembly shall meet the life requirements for each application as defined herein based on a cumulative propellant exposure period of 1500 hours.

3.3.9.1 Mission Service Life. - The tank assembly shall perform as specified for at least 25 complete duty cycles as defined in 3.3.6. This includes system checkout, pre-launch checkout of the reaction control subsystem and one actual space mission of 14 days. The expulsion cycle during the actual space mission will be accomplished over a period of approximately three days.

3.3.9.2 Ground Use Service Life. - The tank assembly shall perform as specified in 3.3.7.

3.3.9.3 Storage Life. - The tank assembly as received from the vendor shall have a storage life of five years with necessary periodic maintenance. Storage life is a design criteria only and does not require demonstration. No permanent weight shall be added to the unit to meet these requirements.

3.4 Environmental Conditions. - The tank assembly shall operate within the requirements specified herein during and after exposure to all possible combinations of the environmental conditions of Table I times the applicable yield.

3.4.1 Radiation Environment. - Charged particle radiation and electromagnetic radiation originating from the sun and other celestial sources shall be considered in the design of the assemblies. In addition the radiation effects of the quantity gaging equipment as supplied by Grumman shall be considered.

3.5 Reliability. -

3.5.1 Mission Success. - The mission success reliability goal for each tank assembly shall be 0.9995. This goal applies to nominal tank performance during the actual space mission under the environmental parameters of Table I, Section C through G.

3.5.2 Reliability Boundary. - The Reliability Boundary conditions of the tank assembly shall be as described in 4.4.1.2.1.1.1.

3.6 Interchangeability. - All parts having the same manufacturer's part number shall be functionally and dimensionally interchangeable.

3.6.1 Interchangeable Items. - The following listed items covered by this specification shall be interchangeable:

(a) Tank Assembly

(b) Tank Shell Subassembly

(c) Positive Expulsion Device

3.7 Mechanical Resonance Frequency. - The mechanical resonance, or natural, frequency shall not be less than 60 cps when the tank assembly is fully loaded with propellants.

3.8 Design. - The assembly shall be designed to and shall meet the requirements of this specification.

3.8.1 Details.

3.8.1.1 Seals. - Dual seals shall be provided at any interface between the tank shell subassembly and positive expulsion device. The seal design shall permit it to function to design requirements by the clamp-up action of the cover bolts and without the use of adhesive or other additional sealing preparations.

3.8.1.2 Fastening Devices. - All fastening devices, including those with self-locking feature, shall incorporate positive safetying provisions. Fastening devices which place threads in bearing shall not be used.

3.8.1.3 Closeout Device Attaching Bolts. - The bolts used to attach the closeout device to the tank shell sub-assembly shall have an anti-gall coating and other necessary features to insure proper installation without damage to the threaded portions of the tank or bolt.

3.8.2 Maintainability. - The design shall include connections, fittings, and similar items as well as access to them and access for replacement of assemblies, servicing, and adjustment. These features shall be subject to Grumman approval and shall be provided as shown necessary by the Reliability Analysis and the Maintainability Analysis, performed during preliminary design stages as required by the Purchase Order.

3.8.3 Accessibility. - Access shall be provided for installation, inspection and maintenance of the tank assemblies. Access shall require a minimum of disassembly or displacement of parts, readjustments, resealing, reinspecting, special tools or equipment.

3.8.4 Structural Design Criteria. - The structural design criteria specified below shall be applied to the oxidizer and fuel tank assemblies. All designs shall have positive margins of safety. Transportation, handling and storage in the shipping container shall not produce critical design loads on the tank assembly and shall not increase the weight.

3.8.4.1 Strength and Stiffness. - The level of structural strength and stiffness shall be rationally established by the conditions specified herein plus the specific loadings applicable to the tank assembly. This level shall be called limit load. Factors of safety shall be multiplied

3.8.4.1 (Continued)

by these limit loads. Rational allowances shall be made and incorporated in the limit loads for at least the following:

(a) Stress concentrations

(b) Fatigue

(c) Thermal Stress

(d) Dynamic response

(e) Vibrational amplification

(f) Combinations of environmental conditions given in Table I and/or self-generated loads.

<u>NOTE</u>: Mission levels are limit loads except for vibration paragraph 3.8.4.3.1 (b) and (c).

3.8.4.1.1 <u>Ultimate Factor of Safety</u>. - The ultimate factor of safety shall be not less than 1.5. This factor of safety shall be increased in weld areas as required in 3.8.4.5. At limit load times the ultimate factor of safety, there shall be no structural failure.

3.8.4.1.2 <u>Yield Factor of Safety</u>. - The yield factor shall not be less than 1.33. This factor of safety shall be increased in weld areas as required in 3.8.4.5. At limit load times the yield factor of safety there shall be no permanent deformation which could prevent the tank assembly from complying with the performance requirements.

3.8.4.2 Pressure Vessel Design Factors. - Structural design of pressure vessels shall meet the requirements of two separate analyses. The first shall be combination of pressure and external loads with the requirements of 3.8.4.1 taken into account. Structures shall not require pressure stabilizing systems. When pressure loads are relieving, minimum pressure shall be used. The second shall consider pressure loads only and shall use the factors of safety given below. Limit pressure shall not be less than the maximum expected operating pressure (MEOP) for the system. For structural design, pressure vessels shall include valves, piping, etc., as well as tanks.

3.8.4.2.1 Pressure Vessel Proof Factor. - The proof factor shall be 1.33 applied to limit pressure. After exposure of the pressure vessel to limit pressure times the proof factor, the tank assembly shall be fully capable of meeting the performance specified herein.

3.8.4.2.2 Pressure Vessel Ultimate Factor. - The ultimate factor of safety for pressure vessels shall be 1.50 applied to limit loads. At limit load times the ultimate factor, there shall be no failure of the pressure vessel.

3.8.4.3 Vibration Design Factors. - For structural limit loads, the following factors of safety shall be applied to the vibration amplitudes of Table I. The applied vibrational environment for launch and boost, translunar, descent and ascent phases of the mission consists of random excitation up to 2000 cps. The high acceleration density levels at low frequencies are presented for use in design analysis only since available test equipment is incapable of reproducing the complete spectrum. The test requirements include separate sinusoidal vibrations to account for this low frequency portion of the random spectrum as well as to determine the design adequacy in individual vibrational modes. See test requirements of 4.4.2.2.2.10 and Table IV (Qualification Test Conditions) for test procedures and times. Test requirements shall be considered as part of the vibration design.

3.8.4.3.1 Limit Loads. -

(a) Prelaunch Packaged and Unpackaged - Sinusoidal levels - 1.0 applied to g and double amplitude.

(b) Launch, Boost, Translunar, Descent, Stay, and Ascent Sinusoidal Levels - 1.3 applied to g and double amplitude.

(c) Random Levels During All Phases - $(1.3)^2$ applied to g^2/cps.

3.8.4.3.2 Ultimate Loads. -

(a) Prelaunch Packaged and Unpackaged Sinusoidal Levels - 1.5 applied to g and double amplitude.

(b) Launch, Boost, Translunar, Descent, Stay and Ascent Sinusoidal Levels - 1.5 applied to g and double amplitude.

(c) Random Levels During All Phases - $(1.5)^2$ applied to g^2/cps.

3.8.4.4 Vibration. - The tanks shall suffer no detrimental effects when exposed to the input vibration conditions specified in Table I. For design, the environmental conditions in Table I shall be multiplied by the appropriate safety factors specified in paragraph 3.8.4.3. The vibrational motion amplification factor on any portion of the equipment shall be limited to a maximum of 10 where not already limited to a lower value by other design requirements. This criteria shall be substantiated during development testing. In cases where this requirement appears difficult to accomplish, Grumman shall be consulted for direction before proceeding with the design development.

3.8.4.5 Weld Factor. - For design or welded joints, the stresses due to the MEOP of 3.3.3.2 shall be increased by a factor of 1.33 above those obtained when the factors of paragraphs 3.8.4.1.1, 3.8.4.1.2, and 3.8.4.2.2 are applied.

3.8.5 Fail Safe. - Design shall be such that system, component, assembly, or part failures shall not propagate sequentially, i.e., the design shall be "fail-safe".

3.8.6 Materials, Parts and Processes. - Materials, parts and processes shall be selected to meet detailed requirements determined by design analysis based on function, reliability and the environment generated by operation of the unit, as well as the conditions specified herein. Materials, parts, and processes shall be subject to Grumman approval.

3.8.6.1 Titanium Alloy. - All titanium parts utilized shall be made of a material which, as a minimum, meets with the requirements of MIL-T-9047C, Class 5 or MIL-T-9046C, Class 2. When other requirements of this specification impose higher or more stringent requirements, then the highest or most stringent requirements shall govern. Exception to the chemical composition of MIL-T-9047C, Class 5 is allowed to the extent that the maximum Aluminum content permitted shall be 6.75 percent and not 6.50 percent.

3.8.6.2 Processes. -

3.8.6.2.1 Fabrication and Heat Treat Processes. - Specific fabrication and heat treat processes employed to meet the requirements of this specification shall be established and recorded. These processes as applicable shall include but are not limited to the following:

(a) Annealing and stress relieve temperatures

(b) Preheat cycle

(c) Solution anneal cycles

(d) Aging cycle

(e) Quench media and time

(f) Furnace atmosphere

(g) Tooling and fixtures

3.8.6.2.1 (Continued)

(h) Process, practice, and controls to be used

(i) Capability demonstration - distortion control and correction, metallurgical and mechanical properties.

3.8.6.2.2 Welding. - All welding of the tank shell subassembly shall be performed by Grumman approved methods of mechanized tungsten (TIG) inert gas process using an inert gas chamber or equivalent local inert gas shielding. Criteria for approval shall be in accordance with Section 4 of this specification.

3.8.6.2.2.1 Type of Weld. - Only butt welds shall be permitted on the tank shells.

3.8.6.2.2.2 Inert Shielding Gas. - Inert gas used for shielding shall be:

(a) Argon in accordance with MIL-A-18455B.

(b) Helium Grade A in accordance with U.S. Department of Interior Bulletin 585.

(c) Any combination of (a) and (b) of a grade specifically designated for welding, and with a maximum dew point of -65°F.

3.8.6.2.2.3 Other Weldments. - Manual welding is permitted provided welding is performed in an inert gas chamber or equivalent having adequate controls to insure sound welds. Inert gas shall conform to 3.8.6.2.2.2. Welding shall be performed by welders certified to the applicable classification and group as specified in MIL-T-5021C. Visible cracks of any kind in weld metal or parent metal shall not be acceptable. All welds shall be inspected by radiographic methods.

3.8.6.2.3 Filler Wire. - Filler wire used for welding titanium shall be commercially pure titanium in accordance with AMS4951.

3.8.6.2.4 Mismatch. - The allowable mismatch of welded tank sections shall be a maximum of 20% of the material thickness up to 0.045 inch thickness.

3.8.6.2.5 Weld Bead. - The width of tank shell subassembly weld beads shall be no greater than 0.250 inches of any weld joint. The maximum buildup of the weld bead shall be equal to or less than 0.020 inch and the maximum drop-through shall be equal to or less than 0.020 inch.

3.8.6.2.6 Penetration. - Complete 100% penetration shall be achieved throughout the length of all fusion welded joints.

3.8.6.2.7 Planishing. - Weld beads shall not be planished.

3.8.6.3 Material Properties. - Uniaxial material properties of heat treated titanium alloy tank shell subassemblies as determined by room temperature examination of test coupons, shall be in accordance with the following requirements:

	Parent Material	Weld Specimen	
		Longitudinal	Transverse
Ultimate strength (psi) min.	160,000	155,000	130,000
Yield strength 0.2% offset (psi) min.	145,000	140,000	120,000
Elongation (% in 4 Dia) min.	Round Specimen 8		
Elongation (% in 2 inch) min.	Flat Specimen 6	3	4
Reduction of Area % min.	10		

3.8.6.4 Stress Relieving. - All titanium welds shall be aged or stress relieved, or both.

3.8.6.5 Rework Procedures. - Should weld discontinuities be detected in excess of the requirements of 4.4.1.1.5, the defective areas shall be repair welded using the procedure developed in paragraph 4.4.1.1.4. No more than two repairs shall be permitted in the same areas.

3.8.7 Dissimilar Metals. - Dissimilar metals shall not be used in contact with each other unless suitably protected against electrolytic and chemical corrosion or deterioration to the extent that no contamination or operational impairment is added to the system for the life of the part. The fluids (3.2) and environmental conditions specified herein shall be considered when determining the existence of an undesirable dissimilar metal combination.

3.8.8 Bonding. - Bonding shall be in accordance with the requirements of LSP-390-001.

3.9 Workmanship. - All phases of workmanship shall be performed in a thoroughly workmanlike manner in accordance with the applicable drawings, specifications and standards. Processes and manufacturing methods, not covered by specifications shall be entirely suitable for the article, and workmanship shall be in accordance with high grade spacecraft practice. The quality of workmanship shall not degrade the reliability, performance and life inherent in the design of the article. All surfaces shall be smooth and free from porosity, burrs, chips, dents, and other irregularities.

3.10 Weight. - The vendor shall endeavor to produce the lightest practical assemblies capable of meeting the requirements of this specification. The specification dry weight shall be as shown in Table V. The vendor shall establish and maintain a weight control program as outlined in the purchase order to insure that the maximum weight is not exceeded.

3.10.1 Moment of Inertia and Center of Gravity. - The vendor shall determine the center of gravity location and the moments of inertia of both assemblies.

3.11 Surface Roughness. - Surface roughness shall be established for all interior and exterior surfaces and specified in accordance with MIL-STD-10A. Values established on Specification Control Drawing LSC-310-405 shall not be exceeded.

3.12 Cleanliness. - The interior of the helium and propellant compartments including the standpipe shall meet the cleanliness requirements of Table VI when tested in accordance with 4.4.3.2.2.6.

3.12.1 Cleaning Process. - The cleaning process shall not impair the cleanliness status or other requirements of the tank assembly.

3.12.1.1 Marking. - Each tank assembly which has been tested in and approved as clean in accordance with 3.12 shall have a suitable permanent warning marking attached to the outside of the tank assembly stating, "OPEN IN CLEAN AREA ONLY."

3.13 Finish. -

3.13.1 Tank Assembly Components. - No finish is required on titanium alloy or corrosion resistant steel components. Aluminum alloy components shall be alodized in accordance with MIL-C-5541 and subsequently treated so as to prevent the reaction of the surface film with the propellants specified in 3.2. The treatment following the alodizing should also minimize particulate contamination of propellants by the alodize film.

3.13.2 Tank Assembly Exterior. - A protective exterior coating which can be stripped readily without damage to the tank assembly shall be provided by the vendor over the finish specified in 3.13.1.

3.14 Marking and Identification. - The tank assembly and its subassemblies shall be marked and identified as specified below:

3.14.1 Identification Terms. -

3.14.1.1 Nomenclature. - Nomenclature shall be the same as the approved title of the specification or drawing to which the item is designed. In all instances, the principal identifying noun or noun phrase shall appear first. Where limitation of space precludes spelling out the entire title, it may be abbreviated to the following extent: the principal noun or noun phrase shall be spelled out and the significant modifiers (which establish accurate identification) abbreviated per MIL-STD-12B.

3.14.1.2 Design Control Number. - This number is used to identify design control documents (e.g.: Grumman or vendor specification number). It is assigned by the design activity whose specifications and engineering drawings control the design and production of an item.

3.14.1.3 Serial Number or Lot Number. - Serial or lot number assignment shall be established by procedure subject to Grumman approval. These numbers shall be unique and consecutively assigned to items bearing the identical manufacturer's part number.

3.14.1.4 Contract Number. - The contract number (NAS 9-1100) identifies the NASA/Grumman contract for the LEM. This number shall be marked on all items. In addition, each item shall be marked with the applicable Purchase Order (P.O.) number.

3.14.1.5 Manufacturer's Part Number. - The manufacturer's part number shall be the number identifying the drawing (including dash number(s) if the drawing is tabulated or multidetail) to which an item is actually manufactured. Numbers assigned to identify sales, outline, installation, specification control or purchase control drawings for procurement of items by contractors shall not be used as the manufacturer's part number. An item shall always be identified by the part number assigned by the manufacturer throughout its life, regardless of where used.

3.14.1.6 Manufacturer's Name, Trademark or Code Symbol. - The name, trademark or code symbol entered shall be that of the activity who establishes and is responsible for the manufacturer's identification, provided it is clearly separated therefrom by a dash, slash, parenthesis, or other suitable means.

3.14.1.7 Special Characteristics and Information. - Under this heading pertinent rating, operating characteristics, assembly date and other information necessary for identification, if any, may be entered.

3.14.1.8 U.S. - The notation "U.S." shall denote Government ownership. Other notations such as USA, NASA or LEM shall not be used.

3.14.2 Identification Data Requirements. - All items shall be identified in accordance with this specification prior to being subjected to their quality assurance requirements.

The following data shall apply to all items:

Nomenclature

Design Control No. (The applicable Grumman Specification Control Drawing No. and dash number)

Serial Number

Contract Number

Manufacturer's Part Number

Manufacturer's Name, Trademark or Code Symbol

Special Characteristics (when applicable)

U.S. (Notation)

3.14.3 Location of Nameplate or Markings. - Wherever possible, the nameplate or marking shall be visible and readable after the item is assembled or installed.

3.14.3.1 Identification of Items Without Suitable or Sufficient Marking Surface. - Items which do not have suitable or sufficient surface to reflect the complete identification data shall, as a minimum, be identified with the manufacturer's part number and the serial or lot number. Where this is not possible, the item shall be accompanied by suitable means of identification subject to Grumman approval.

3.14.3.2 Identification of Unmarked Items Subject to Removal After Installation. - The identification of unmarked items subject to removal after installation shall be applied to the item to which the unmarked item is assembled. This marking shall be on a surface adjacent to the unmarked item when assembled.

3.14.3.3 Items Intended for Permanent Installation. - Items which lose their identity after installation (e.g.: items installed by welding and non-removable hardware) shall not be re-identified.

3.14.4 Reworked or Selected Items. - Items reworked or selected for special fit, performance or tolerance shall require new or supplemental identification data as specified in 3.14.2.

3.14.5 Methods of Marking. - Identification of items shall be accomplished by marking methods, materials, and nameplates which will not adversely affect the life or utility of the items to which they are applied. All markings shall be capable of withstanding the environmental and life expectancy of the item to which they are attached, and shall be permanent and legible for ready identification.

3.14.5.1 Selection of Materials and Methods of Application. - Identification shall be accomplished by one of the following methods:

3.14.5.1 (Continued)

(a)	Nameplates (wrap around tags)	Attached by a method allowing alteration of data without requiring re-testing per Section 4.
(b)	Stencil or decalcomania transfer	Applied over exterior finish and removable or otherwise alterable without affecting the exterior finish.
(c)	Acid or electric etching or engraving	Shall be located where obliteration and additional markings may be added without testing.
(d)	Branding, embossing or molding	Shall be used following the procedure for (c) above. Approval for use of these methods shall be received from Grumman Structural Engineering via Purchasing.

(e) Other methods may be used provided they are entirely suitable for the intended purpose. Methods and materials are subject to Grumman Engineering approval.

4 QUALITY ASSURANCE PROVISIONS

4.1 General. - This section of the specification establishes the general test and inspection requirements to be followed during the propellant tanks test program. The vendor may propose additional tests to further increase the effectiveness of this program. The program shall consist of the following test categories:

(a) Development Tests

(b) Qualification Tests

(c) Acceptance Tests

4.1.1 Witnessing of Tests. - Grumman and the designated government inspection agency shall be advised 48 hours in advance when scheduled tests are to be conducted so that a representive may be designated to witness the tests.

4.2 Test Facilities. -

4.2.1 General. - Private, commercial or government test facilities may be used subject to Grumman approval of the test plan.

4.2.2 Environmental Test Facilities. - The environmental test facilities used in conducting tests shall be capable of producing and maintaining the test conditions outlined in the test plan. These facilities shall be of a capacity and/or volume such that the item under test shall not interfere with the generation and maintenance of the required test conditions.

4.2.2.1 Environmental Protection. - Equipment which requires special environmental control, such as hermetic sealing, insulation, vibration isolation, etc., shall be tested with the special environmental control applied.

4.2.3 Standard Conditions. - Tests conducted without utilizing special environments shall be conducted under the following standard ambient conditions:

(a) Temperature $77^{\circ} \pm 20^{\circ}F$

4.2.3 (Continued)

(b)	Relative Humidity	100% or less
(c)	Barometric Pressure	Local Atmospheric

4.2.4 Instrumentation Calibration. - All instrumentation shall be in accordance with MIL-C-45662A.

4.2.4.1 Tolerances

(a) Test Equipment - Equipment to measure the tank assembly parameters shall have an accuracy of one order of magnitude (factor of ten) greater than the required accuracy of the measurement to be made. Deviations from this requirement shall have approval by Grumman.

(b) Test Conditions - The tolerance on test conditions shall be specified for each test. Acceptable values are:

(1) Temperature $\pm$ 3.0°F

(2) Vibration Amplitude $\pm$ 10%

(3) Vibration Frequency $\pm$ 2%

(4) Random Vibration: The vibration acceleration density applied to the test item shall be within $\pm$ 3 db of the specified test level over broad regions of the spectrum between 20 and 1000 cps and $\pm$ 4 db between 1000 and 2000 cps.

(5) Shock Amplitude $\pm$15%

(6) Acceleration Amplitude $\pm$ 5%

(7) Barometric Pressure $\pm$ 2%

(8) Humidity $\pm$5%

4.2.4.1 (b) (Continued)

(9) Time ± 5%

(10) Pressure ± 5%

(11) Flow Rates ± 5%

4.2.5 Sensing and Recording Equipment. - Sensing and recording equipment of adequate response shall be used to obtain data during transient conditions of the tank assembly operation requiring the evaluation of time versus test data.

4.2.6 Mounting Fixtures. - The mounting fixtures shall expose the items under test to the dynamic test environment in a manner that is representative of that in which it will be exposed in the LEM System.

4.3 Test Procedures. -

4.3.1 Operational. - The tank assembly shall be subjected to the operational test specified below. The test shall be performed twice: Once with the propellant temperature stabilized at 40°F or lower; the second time with the propellant temperature stabilized at 100°F or higher. The test shall be used to verify filling methods and expulsion efficiency. The tank outlet and tank vent shall be oriented downward during filling and upward during expulsion. Expulsion shall be performed such that oxidizer flow rates of 0.22, 0.44 and 0.88 lbs/sec are used for 60, 30 and 10 percent of the test duration respectively. (Fuel flow rates of 0.11, 0.22 and 0.44 lbs/sec would apply in similar manner.)

(a) Fill the propellant side of the system with the tank vent opened to the fill station return line. This line shall have a pressure control to assure that tank pressure is above the vapor pressure of the fuel and oxidizer.

4.3.1 (Continued)

(b) Fill the tanks, both oxidizer and fuel, to the maximum full level. This will be accomplished when a steady flow of liquid is discharged through the tank vent.

(c) Close off the fill and return connections.

(d) Apply a helium pressure of 25 psig to the tanks.

(e) Open the return connection and bleed off the required amounts of ullage by weight, through the tank vent into the fill return lines.

(f) Close off the return connection.

(g) Apply helium at a temperature no warmer than 40°F with 40°F propellant and helium no colder than 100°F with 100°F propellant and at a pressure of 181 $\pm$4 psig to the inlet port and expel the propellant using flow burst of random duration varying from 5 seconds to 360 seconds.

(h) Compliance with the requirements of 3.3.3.5, 3.3.4 and 3.3.5 shall be determined during filling and expulsion.

(i) Record and report fill capacity and propellant expelled.

4.3.1.1 Acceptance Operational Test. - The tank assembly shall be subjected to the operational test specified below. The test shall be performed with a simulated propellant. The test shall be used to check filling and expulsion efficiency. The tank outlet and tank vent shall be oriented downward during filling and upward during expulsion.

(a) Fill the propellant side of the system with the the tank vent open.

(b) Fill the tanks to a maximum full level. This will be accomplished when a steady flow of liquid is discharged through the tank vent.

4.3.1.1 (Continued)

(c) Close off the fill and return connection.

(d) Apply a helium pressure to the tanks.

(e) Open the return connection and bleed off the required amounts of ullage by weight, through the tank vent.

(f) Close off the return connection.

(g) Apply helium at ambient temperature (approximately 70°F) at a pressure of no more than 181 psig to the inlet port and expel the simulated propellant, not exceeding maximum flow rate of .88 pounds per second.

4.3.2 Leakage. -

4.3.2.1 Leak Detection. - All sealed compartments of the tank assemblies shall be tested for leakage as specified below. The vendor shall propose methods of leak detection and measurement for each test.

4.3.2.2 External Helium Leakage. - The external leakage test shall determine the amount of helium leakage through the tank shell and through any seals between the interior and exterior of the unit. The proposed test method shall be developed by the vendor to show compliance with the requirements of 3.3.2.2.

4.3.2.3 External Propellant Leakage. - The external propellant leakage test shall determine the amount of propellant leakage from the propellant compartment to the tank exterior. The proposed test method shall be developed by the vendor to show compliance with the requirements of 3.3.2.4.

4.3.3. Proof Pressure. - The assembly without bladder shall be subjected to a hydrostatic pressure of 333 psig minimum for a period of 15 minutes. Strain gages or other approved methods of strain measurement shall be applied during development test only to the unit before the test. At the conclusion of the test, the strain measurement devices shall be examined for evidence of localized yielding. The volumetric change shall be measured and recorded. Evidence of deformation adversely affecting operation shall be cause for rejection.

4.3.4 Burst Pressure. - The assembly without bladder shall be hydrostatically pressurized to failure. The rate of application shall be in increments equal to 10 percent of the burst pressure until proof pressure is reached, then in increments of 5 percent burst pressure for a period of 30 seconds minimum. Between increments the volumetric expansion shall be measured in milliliters to an accuracy of 0.3 milliliters and then recorded. When burst pressure is reached, it shall be sustained for 2 minutes, and recorded unless rupture occurs.

4.3.5 Fluid Compatibility. - The effects on components of the chemical action of the fluids within the specification limits of the fluids as well as the effects of aging with fluids, drying in air, contact with vapors or the worst combination thereof, or both, shall be determined and qualifying criteria shall be proposed in the test plan. The test conditions shall simulate as closely as practicable those encountered in the actual application. This test shall include aging of each component with the fluid with which it is to be used to show compliance with the requirements of 3.3.9.

4.3.6 Volume Verification Test. - This test shall be performed to show compliance with the requirements of 3.2.1.2 and 3.2.2.2 (for oxidizer and fuel tanks respectively.) The assembly shall be filled with the quantity of propellant specified in 3.2.1.2 or 3.2.2.2 at a temperature of no more than $65^{o}F$. With the propellant compartment initially pressurized to no less than 25 psig and the helium compartment positively capped, the assembly shall be heated to a stabilized temperature of at least $100^{o}F$. The resultant propellant compartment pressure shall be recorded and reported.

4.3.7 Slosh. - The slosh test shall be performed with the assembly mounted with its X axis vertical and the propellant compartment filled with simulated propellant to 1/3 capacity. Pressurization of the helium compartment is not required. The slosh test equipment shall produce reciprocating motion and subject the unit to acceleration of 0.1g. The reciprocating motion shall be applied in a direction perpendicular to the X axis. Cycling shall be performed at the natural frequency of the fluid based on the propellant mass and tank configuration. The computed natural frequency shall be checked experimentally by cycling at several frequencies below and

4.3.7 (Continued)

above the natural frequency for several cycles to determine the frequency developing the largest slosh amplitude. A cycle is defined as one slosh impulse. 500 slosh cycles shall be performed. After conclusion of the slosh test, perform the leakage test of 4.3.2.3.

4.3.8 Shock. - The test units shall be mounted in accordance with 4.2.6. The measurement of the shock input shall be accomplished at the mounting interface of the test unit. The test shall be conducted under standard conditions of 4.2.3.

4.3.9 Sustained Acceleration. - The test unit shall be mounted on the test apparatus (centrifuge) in such positions to produce the accelerations shown in Table IV at the tank center of gravity and in the directions specified for a particular test. The test apparatus shall be of such size that the gradient across the test item shall not be greater than ± 25% of the input acceleration through the c.g. of the test item. The test shall be run at standard conditions of 4.2.3.

4.3.10 Vibration. - The vibration shall be accomplished in the three mutually perpendicular directions parallel to the spacecraft x-x, y-y, and z-z coordinate axes. The spacecraft coordinate axes are defined in the specification control drawings. Test units and jig assemblies shall be mounted directly to the shaker head. If this type of mounting is not practicable, slip tables may be utilized. A complete log of each vibration test shall be maintained, including all resonant frequencies, instrumentation used, design changes made, and a detailed account of the performance of the equipment under test. If, in attempting to equalize vibration input or determine fixture resonances, it is necessary to apply vibration energy to test units prior to actual test, the vibration RMS - g value shall be kept to a minimum and shall never exceed 50% of the actual test values.

4.3.10.1 Vibration Fixtures. - The fixtures connecting the test unit with the shaker head shall be capable of transmitting the vibrations specified herein. It shall be a design objective that these fixtures be free of resonances within the test frequencies. In any event, resonant frequencies of fixtures compensated for test unit mass, shall be above 600 cps. The transverse motion (crosstalk) in any direction produced by these fixtures shall not exceed the vibration levels in the transverse direction specified herein. The requirements outlined above shall be verified by a sinusoidal vibration sweep at test frequencies using a mass simulated dummy test item. The vibration input for this sweep shall be monitored with tri-axial or equivalent accelerometers.

4.3.10.2 Sinusoidal Vibration. - A sinusoidal vibration sweep at 50 percent of the required sinusoidal levels shall be conducted. The vibration levels shall be measured at or near each test unit mounting location. Whenever more than four mounting locations exist, only four points need be monitored. Any accelerometer fastened at one of the mounting locations can be used as the servo control input provided that:

(a) The control input maintains levels at the test frequency within $\pm$ 1 db of the requirements.

(b) The level at any input location is within $\pm$ 4 db of the requirements at the test frequency.

(c) The average of all inputs at the test frequency is within $\pm$ 2 db of the requirements.

4.3.10.2 (Continued)

Exceeding the lower limits of the above tolerances shall be cause for rejection of the delinquent portion of the test and shall necessitate rerunning only that portion of the vibration test. The recording of the accelerometer output signals shall be accomplished on a continuous recording device. These signals may be sampled at specific intervals except that they may be continuous during Qualification testing. The recording device shall have a response capability such that the complete signal wave form may be examined and analyzed.

4.3.10.3 Random Vibration. - The vibration input for this test shall be controlled from the same accelerometer as used to control the sinusoidal vibration test. The spectrum at test levels shall be analyzed and a plot of acceleration spectral density (g^2/cps) versus frequency shall be compiled for each random test. The analyzing filter shall have a maximum band width of 1/3 octave or 100 cps, whichever is less.

4.3.11 Endurance Cycling. -

4.3.11.1 Expulsion Device Cycling. - A total of at least 50 expulsions shall be performed as described in 3.3.6 except that two cycles shall be performed such that at the end of the expulsion cycle the helium pressurant tank shall be at a temperature no warmer than -20°F. Testing shall be performed with the tank assembly oriented in three mutually perpendicular axes. Expulsions shall be equally divided between the three orientations. Propellant temperature shall be no warmer than 40°F for one quarter (1/4) of the cycles and shall be no colder than 100°F for another quarter. The remainder of the cycles shall utilize a propellant temperature range of 40°F to 100°F. At the completion of this test, the tank assembly shall be subject to the leakage test of 4.3.2.3.

4.3.11.2 Tank Shell Subassembly Cycling. - The tank shell subassembly and its closeout device shall be subjected to at least 3000 pressure cycles. During each 300 cycle series, 270 cycles shall be performed using a pressure cycle of zero to nominal tank pressure (3.3.3.1) to zero, and 30 cycles shall be performed using a pressure cycle of zero to MEOP (3.3.3.2) to zero. The increasing pressure portion of each cycle shall be completed within 1.5 $\pm$ .25 seconds.

4.4 Tests. -

4.4.1 Development Tests. - Development tests are conducted to provide data to be used in the design or in the support of the design of a specific component or subsystem. Development tests may be used to determine operating characteristics under off-design conditions. Stress-to-failure development tests shall be conducted to provide failure mode and weak link characteristics for verification of analysis and determination of strength margins. In conjunction with the general thermal design, it is required that development tests be run on the equipment under simulated thermal environment to assure the compatibility of the thermal design with the specification. Vibration amplification factors shall be substantiated during development testing. Development tests shall be categorized as follows:

(a) Design Feasibility Tests

(b) Design Verification Tests

Tests under both (a) and (b) will be run with simulated propellants, except for the volume verification test which will use actual propellants.

4.4.1.1 Design Feasibility Tests. - Design feasibility tests shall include all tests conducted for the following purposes:

(a) Component and part selection.

(b) Investigation of the performance of breadboard models, components and subassemblies under various environmental conditions.

(c) Selection of materials.

(d) Substantiation of safety margins or other analytical assumptions.

4.4.1.1.1 Titanium Billets and Forgings. - Titanium billets and forgings shall be in accordance with the applicable portions of 3.1.1.1 and Table VII.

4.4.1.1.2 Titanium Welding. - Weld process approval for a particular weldment shall be granted after a demonstration has proved that the test rings of 4.4.1.1.3 meet the tensile strength requirements of 3.8.6.3. Premature failure of a test ring or component weld, shall require weld process reapproval. Repair welds shall also meet the requirements of 3.8.6.3.

4.4.1.1.3 Titanium Test Rings. - The strength, ductility, and the potential effect of weld defects shall be evaluated by circumferentially welding four test rings of the diameter of the propellant tanks and thickness of the weld reinforcement section. The welding processing details and procedures shall be identical to those to be employed in the fabrication of the propellant tanks. Each test ring shall be inspected for compliance with welding requirements of paragraph 3.8.6.2 and 4.4.1.1.5. A minimum of three (3) longitudinal and six (6) transverse tensile test specimens as shown in Figure 2, shall be machined from each ring and tested to evaluate the efficiency of the weld. Locations and condition of all tensile test specimens shall be in accordance with approved procedures prior to machining and testing as per FED-STD-151 Method 211. Weld bead reinforcement shall be on or off, whichever is planned for the production tanks. In the event that a welding process change is planned during fabrication of the propellant tanks which may affect the joint efficiency, four additional test rings as described above shall be prepared for test.

4.4.1.1.4 Titanium Repair Welds. - The feasibility of producing sound repair welds and multiple repair welds shall be demonstrated by fabricating four additional test rings and testing each ring as follows:

(a) 1st 120 degree segment — Single Weld

(b) 2nd 120 degree segment — Repair Once

4.4.1.1.4 (Continued)

(c) 3rd 120 degree segment Repair Twice

The longitudinal and transverse tensile specimens shall be taken from each segment of each ring. The weldment shall be 100 percent radiographically inspected. The results shall be submitted to Grumman for approval. If additional repairs and procedures are anticipated, such repairs and procedures shall also be demonstrated.

4.4.1.1.5 Weldment Discontinuities. -

4.4.1.1.5.1 Porosities. -

(a) Sizes greater than 0.012 inch diameter are unacceptable

(b) The spacing of pores greater than 0.007 inch diameter and up to and including 0.012 inch diameter shall not be less than 0.150 inch.

(c) The spacing of pores less than and equal to 0.007 inch diameter shall not be less than 10 diameters of the largest pore with a minimum spacing of 0.040 inch allowable.

(d) The spacing of pore combinations listed in items (b) and (c) in addition to meeting the above requirements shall not be less than 0.125 inch.

(e) A maximum of 7 pores per inch shall not be exceeded.

(f) Elongated porosity in which the major axis is greater than twice the minor axis is unacceptable.

(g) Porosity with tails is unacceptable.

(h) Surface pores larger than 5 percent of material thickness are unacceptable.

4.4 1.1.5.2 Tungsten or Other Inclusions. -

(a) Sizes greater than 0.007 inch are unacceptable.

(b) Spacing less than 0.250 inch is unacceptable

(c) Total number shall not exceed 5 per weldment

4.4.1.1.5.3 General. - A cluster is defined as 3 to 5 pores per inch. The spacing between clusters shall not be less than one inch and a maximum of 4 clusters per linear foot shall not be exceeded. Inclusions will not be allowed within any porosity cluster and shall be spaced a minimum of 0.250 inch from a cluster.

4.4.1.1.5.4 Incomplete Penetration. - Unacceptable.

4.4.1.1.5.5 Cracks. - Unacceptable.

4.4.1.1.5.6 Under Cut of the Weld Bead Below the Face of the Parent Metal. Unacceptable.

4.4.1.1.5.7 Concavity of the Weld Bead Under the Face of the Parent Metal. - Unacceptable.

4.4.1.1.5.8 Visual Appearance. - Discoloration or other evidence of contamination is unacceptable.

4.4.1.1.6 Heat Treat. - The metalluriqical test samples required by 4.4.1.1.3 shall be subjected to the same heat treat cycle as the production tank. Tensile specimens may be straightened prior to heat treat.

4.4.1.1.7 Mechanical Properties. - Ultimate strength, yield strength, and elongation, of each tensile specimen shall be determined per FED-STD-151 Method 211.

4.4.1.1.7.1 Microspecimen. - The microspecimen M of Figure 2 shall be examined as follows:

(a) Microetch-Photographs (2x) shall be taken of the weldment cross-section as etched.

4.4.1.1.7.1 (Continued)

(b) Microhardness testing-Microhardness surveys (Knoop 200-gram identure or equivalent) shall be conducted on the weldment cross-sections (weld bead through heat affected zone to parent metal).

(c) Microetch-Photomicrographs (100X) shall be taken of each weldment cross-section

4.4.1.1.8 Weldment Inspection. - Each titanium weldment shall be visually inspected and 100% radiographic and fluorescent penetrant inspected after welding, for compliance with 4.4.1.1.5 prior to further processing. All other weldments must be 100% radiographically inspected.

4.4.1.1.8.1 Radiographic Inspection. - Weldments shall be 100% radiographically inspected per MIL-STD-453.

4.4.1.1.8.2 Fluorescent Penetrant Inspection. - All titanium weldments shall be 100% inspected per MIL-I-6866A using Group V post emulsified penetrant per MIL-I-25135C, after final processing and after acceptance tests are completed.

4.4.1.1.9 Titanium Heat Treat Test Specimens. - Six test specimens shall be machined from equally spaced locations on trepanned discs or trim rings of each heat treated forging. Three specimens shall be tested to check the acceptability of the forging per Table VII. During the stress relief or aging of each tank, three test specimens originating from each forging shall be suspended at equally spaced locations around the tank and tested to check the final properties of the tank per 3.8.6.3.

4.4.1.1.10 Measurement. - Each tank subassembly wall shall be inspected dimensionally prior to welding and each tank shall be inspected dimensionally after stress relief, aging or final machining whichever is last for conformance to the requirements of Specification Control Drawing LSC-310-405A.

4.4.1.1.10.1 Wall Thickness. - Wall thickness measurements shall be conducted by a measuring device that shall have an accuracy of 0.001 inch before welding. After welding wall thickness measurements shall be conducted by Videgage method or equivalent, that shall have an accuracy of 0.002 inch or plus or minus 0.1 percent of the wall thickness, whichever is greater.

4.4.1.2 Design Verification. - Design verification tests are advance stage development tests which are performed on components and subsystems for the purpose of substantiating the correctness of the design for its intended mission. These tests shall be conducted under simulated mission environments and off-design conditions. Successful design verification and tests provide the assurance necessary to permit a design freeze decision to be made. These tests shall include the requirements of 4.4.1.1 using simulated propellants with the exception of volume verification testing.

4.4.1.2.1 Reliability Assurance. - As an integral part of the development test program, the vendor shall meet the requirements of 4.4.1.2.1.1. This requirement shall be satisfied for the highest order of assembly deliverable to Grumman. Tests applicable to reliability assurance shall fulfill the following essentials:

(a) The tests are conducted on equipment which is representative in design, physical configuration and material to deliverable flight weight equipment.

4.4.1.2.1 (Continued)

(b) The above equipment is tested to failure under systematically increasing dynamic and environmental stresses. Failure is described as deviation of performance from the minimum acceptable operating mode. Attention is to be given to subjecting the equipment to combined dynamic loads and environments whenever the combined effects exist and may be critical. Operating time or number of cycles shall not be overlooked as possible criteria variables.

(c) Prior to the stress-to-failure tests, the above equipment shall have been subjected to one mission simulation at the reliability boundary conditions of 4.4.1.2.1.1.1. The mission simulation shall take into account the critical environments and dynamic conditions to which the equipment will be exposed during the acceptance tests, handling, transportation, and storage, prelaunch, launch, translunar, and lunar phases of the LEM mission.

4.4.1.2.1.1 Reliability Assurance Requirements. - The equipment shall fulfill the following requirements:

(a) All equipment tested shall survive one mission simulation at Reliability Boundary Conditions without failure.

(b) In the stress-to-failure test, no failure shall occur at levels of severity lower than the most critical conditions of the qualification test.

4.4.1.2.1.1.1 Reliability Boundary. - The Reliability Boundary for vibration, shock, acceleration and temperature storage shall be in accordance with Table IV, Qualification Tests. The Reliability Boundary for slosh and expulsion cycling shall be in accordance with 4.3.7 and 4.3.11.1 respectively.

4.4.1.2.1.1.2 Analysis of Results. - The vendor shall perform an engineering analysis of the data generated by the stress-to-failure tests including a correlation with the Failure Mode Prediction Analyses and submit the data and the analysis to Grumman.

4.4.2 Qualification Tests. - Qualification tests are conducted on samples identical to production tank assemblies for the purpose of verifying their complete suitability.

4.4.2.1 General. - Prior to any qualification tests, the tank assemblies will undergo acceptance tests in accordance with paragraph 4.4.3. The tank assemblies and test apparatus shall be subjected to inspection by Grumman quality control representatives. At convenient times prior to and after the tests, the tank assemblies shall be examined to determine if it conforms to all requirements. At the option of Grumman, measurements shall be made of critical tank assemblies dimensions prior to start of the qualification tests. The results of these examinations shall be a part of the qualification test data. Tank assemblies that have undergone qualification tests shall not be used for qualification testing as part of a higher order assembly.

4.4.2.1.1 Parts Failure and Replacement. - Maintenance, adjustment, or replacement of parts shall not be permitted during qualification testing except when approved by Grumman.

Tank Assembly - If during the qualification test of the tank assembly a part fails, this part may be replaced if economically justifiable, or a new qualification test may be started on a new tank assembly. The replacement part shall be a redesigned part or one of different material unless Grumman authorized the installation of a new part of original design and material for one which in their opinion failed due to sub-standard material or workmanship. The qualification test on each tank assembly shall be considered complete when every part of the tank assembly has been subjected to and has satisfactorily completed the entire test. At the discretion of

4.4.2.1.1 (Continued)

Grumman redesign and retesting may be required of any part which fails or indicated weakness after completing its qualification test but which is retained to complete testing on other parts.

4.4.2.2 Tank Assembly Inspection and Tests. -

4.4.2.2.1 Tank Assembly Inspection Before Tests. - All components shall be completely inspected for compliance with the drawings and specifications prior to qualification testing. Deviations from the drawings and specifications shall be cause for rejection unless approved by Grumman. Defective parts shall not be used on any tank assembly subjected to the qualification tests.

4.4.2.2.2 Tank Assembly Tests. - The tank assemblies shall be subjected to the tests listed in Table II. The vendor shall schedule these tests in the test plan. The order of occurance of the environments during mission shall be the preferred order for test scheduling. The vendor shall determine and state in the test plan, the applicability of the following procedures for the individual tests:

(a) Pre-exposure examination, leak check and operational use as required.

(b) Exposure to environments, leak check and operational tests as required.

(c) Post-exposure examination, leak check and operational tests as required.

4.4.2.2.2.1 Operational. - The tank assemblies shall be subjected to the operational test of 4.3.1, with actual propellants.

4.4.2.2.2.2 Leakage. - The tank assemblies shall be subjected to the leakage tests of 4.3.2.3.

4.4.2.2.2.3 Proof Pressure. - The tank assemblies shall be subjected to the proof pressure test of 4.3.3.

4.4.2.2.2.4 Burst Pressure. - The tank assemblies shall be subjected to the burst pressure test of 4.3.4.

4.4.2.2.2.5 Volume Verification. - The tank assemblies shall be subjected to the volume verification tests of 4.3.6.

4.4.2.2.2.6 Slosh. - The tank assemblies shall be subjected to the slosh tests of 4.3.7.

4.4.2.2.2.7 Extreme Temperature. - The tank assemblies shall be subjected to a high and low temperature environment in a thermal environmental chamber at atmospheric pressure. All tests will then proceed as follows:

(a) Low Temperature - The temperature of the unloaded assemblies shall be lowered to the minimum value of Table IV. The assemblies shall be maintained at this temperature for a minimum of 12 hours after the temperature has been stabilized. The equipment need not operate during this test, however, it shall survive the extreme temperature and a performance test in accordance with the procedure of 4.3.1 which shall be performed after the test.

(b) High Temperature - The procedure for the low temperature test shall be repeated except that the equipment shall be heated by suitable means to the high temperature extreme of Table IV. This test will be combined with the operational test of 4.3.1.

4.4.2.2.2.8 Shock. - The tank assemblies shall be subjected to the shock loads of Table IV.

4.4.2.2.2.9 Acceleration. - The tank assemblies shall be subjected to the acceleration loads of Table IV.

4.4.2.2.2.10 Vibration. - The tank assemblies shall be subjected to the vibration specified in Table IV using the procedure of 4.3.10.

(a) Resonance Search - A sinusoidal resonance search shall be conducted at half or less of the required sinusoidal qualification test levels before any portion of the vibration test is conducted. Resonant frequencies and vibration amplifications shall be noted in the test log. The vibration amplification of any portion of the equipment shall be in accordance with 3.8.4.4.

4.4.2.2.2.11 Endurance Cycling. - The tank assemblies shall be subjected to the endurance cycling test of 4.3.11.

4.4.2.2.2.12 Additional Tests. - Additional tests, for the purpose of testing special features of the tank assembly may be required.

4.4.2.2.2.13 Weight. - The tank assemblies shall be weighed and their weight shall not exceed the values specified in this specification.

4.4.2.2.3 Tank Assembly Inspection After Tests. - After completion of tests each assembly shall be subjected to a visual examination and measurements taken, as necessary, to disclose excessively worn, distorted, or weakened parts. Following this, the positive expulsion device shall be removed for a similar examination. Photographs shall be taken of such discrepant parts and these photographs shall be included in the test report.

4.4.2.2.4 Qualification Conditions. - Qualification of each tank assembly shall be predicated on maintenance of all parameters within specified limits.

4.4.3 Acceptance Tests. - Acceptance tests are tests conducted on deliverable items to provide assurance that the equipment performance is within the limits of the design parameters and that the equipment is free from material, construction, workmanship and functional deficiencies. All tank assemblies delivered for fulfillment of the Purchase Order shall be subjected to an acceptance test.

4.4.3.1 General. - The tank assemblies and subassemblies, the test apparatus and the material entering into the manufacture of articles for fulfillment of the Purchase Order shall be subjected to inspection by authorized Grumman representatives. At convenient times prior to the tests and after the tests, the tank assemblies and subassemblies shall be examined to determine if they conform to all requirements of the Purchase Order and specifications. Acceptance test conditions shall not be more severe than expected mission conditions and factors of safety and margins on life shall not be included in determining the environment for these tests. Items for use on flight spacecraft shall not contain a component or element which has been subjected to more than two (2) acceptance test programs nor component or element which has been subjected to environments of an intensity higher than acceptance test levels.

4.4.3.2 Tank Assembly Inspection and Tests. -

4.4.3.2.1 Tank Assembly Inspection Before Acceptance Tests. - Each tank assembly shall be completely assembled in accordance with the drawings, then visually and dimensionally inspected before commencing the tests.

4.4.3.2.2 Tank Assembly Tests. - Each tank assembly as assembled for the inspection specified in 4.4.3.2.1 shall be subjected to the tests outlined in Table III and as specified in paragraphs 4.4.3.2.2.1 through 4.4.3.2.2.6.

4.4.3.2.2.1 Weight. - The tank assemblies shall be weighed, their weight shall not exceed the value specified in Table V of this specification.

4.4.3.2.2.2 Operational. - The tank assemblies shall be subjected to an operational test using the procedure of 4.3.1.1.

4.4.3.2.2.3 Leakage. - The tank assemblies shall be subjected to leakage tests using the procedure of 4.3.2.2 and 4.3.2.3.

4.4.3.2.2.4 Proof Pressure. - The tank assemblies shall be subjected to a proof pressure test using the procedure of 4.3.3.

4.4.3.2.2.5 Vibration. - The empty tank assemblies shall be subjected to random vibration tests using the procedures of 4.3.10 with the levels of Table III.

4.4.3.2.2.6 Rinse Test. - The cleanliness of the tank assembly propellant compartment shall be verified by a rinse test. For each square foot of effective surface 200 ml of a suitable rinse test fluid shall be placed in the tank and sloshed or agitated around the effective surfaces to insure entrainment of particles. The effluent of the rinse test shall be examined for particulate in accordance with SAE-ARP-598 (or equivalent method) for the requirements of Table VI. Nitrogen per MIL-P-27401B, Type I filtered through a 5 micron nominal, 10 micron absolute filter may be used to purge the tank.

4.4.3.2.3 Acceptance Conditions. - Acceptance of the tank assemblies shall be predicated on maintenance of all parameters within the limits specified throughout all tests.

4.4.3.2.4 Tank Assembly Inspection Test. - Upon completion of the acceptance tests, the tank assemblies shall be subjected to external visual inspection. If any part is found to be defective, an approved part shall be supplied to replace it, and a suitable penalty test shall be conducted at the discretion of Grumman.

4.4.3.2.4.1 Tank Assembly Penalty Test. - The maximum penalty test shall consist of a repetition of the test runs outlined under paragraph 4.4.3.2.2. Should the total number of positive expulsion cycles during the penalty tests on a component exceed that normally accumulated during the acceptance test runs, the assembly shall be rejected and shall become unacceptable for use on flight spacecraft.

4.4.3.2.4.2 Tank Assembly Inspection After Penalty Test. - Upon completion of the penalty test, the tank assemblies shall be visually inspected.

4.4.3.2.5 Rejection and Retest. - Whenever in the opinion of the Grumman representative, there is evidence of malfunctioning or evidence that the tank assembly is not meeting the specified requirements, the difficulty shall be investigated and its cause corrected to the satisfaction of the Grumman representative before the test is continued. At the option of the Grumman representative, that portion of the test in which the difficulty was encountered shall be repeated.

4.4.3.2.5.1 Maximum Number of Positive Expulsion Cycles. - Tank assemblies shall be rejected whenever the total number of positive expulsion cycles accumulated during the tests specified herein exceeds the time allowed for acceptance test.

5 PREPARATION FOR DELIVERY

5.1 General. - The preparation for delivery shall render the tank assemblies capable of shipment without degradation of reliability because of corrosion, contamination or physical damage from slosh, and vibration or other shipping hazards encountered during handling and transportation to Grumman.

5.1.1 Procedures. - Written procedures shall be submitted to Grumman for preservation in packaging in accordance with Section E of the purchase order.

5.2 Preservation and Packaging. - The tank assemblies shall be packed in such a manner as to meet the environmental requirements stated in Table I of this specification. Cleanliness of the barrier materials shall be the same as/or greater than the cleanliness level of the equipment being packaged.

5.3 Adequacy of Packaging and Packing. - Adequacy of the packaging and packing shall be verified by tests according to Method 516, Procedure III of MIL-STD-810. Tests shall be performed on the packaged equipment or a dummy load substituted for the equipment. The equipment or dummy load shall be instrumentated to determine the maximum acceleration and pulse duration experienced along three major axes of the equipment. Location of the accelerometers shall be approved by Grumman. Recorded accelerations during the tests shall not exceed the design shock limit levels for the equipment.

5.4 Marking of Shipments. - Interior and exterior containers shall be durably and legibly marked such that the markings shall provide the following information:

Item Name ______________________
Contractor's Control No. __________
Stock No. ______________________
Contractor's Order No. ___________
Manufacturer ____________________
Mfg.'s Serial No. ________________
Date of Manufacture ______________

6 NOTES - Not applicable

TABLE I

ENVIRONMENTAL AND LOAD CONDITIONS

NOTES:

1. Factors of safety are not included in the levels specified herein. Factors of safety shall be applied to these values and self-generated structural loads of each subsystem.
2. All accelerations are "earth g's". Multiply by earth weight or use 32.2 ft/sec^2 as appropriate.
3. Vibration spectra herein refer to straight lines on a log-log plot.
4. "Packaged" means ready for shipment in the special shipping and storage container.

(a) Prelaunch Packaged (Tanks Empty and Slightly Pressurized) for Transportation, Handling and Storage

Acceleration: (ns) 2.67g vertical with 1.0g lateral applied to package.

Shock: (ns) Transportation, handling and storage in the shipping package shall not produce critical design loads on the propellant tank assembly and shall not effect an increase in weight.

Shock as in MIL-STD-810(USAF) 14 June 1962 Method 516, Procedure III.

Vibration: (ns) The following vibration levels are specified during transportation, handling and storage. Vibration to be applied, along three mutually perpendicular axes, x, y, and z to the package. (1/2 octave per minute.)

(ns) These levels of Environments and Loads do not occur simultaneously.

TABLE I (Continued)

(a) (Continued)

	cps	g or D.A.
	5-7.2	.5 inch D.A.
	7.2-26	± 1.3g
	26-52	.036 inch D.A.
	52-500	± 5.0g
*Pressure:	Atmospheric pressure corresponding from sea level to 50,000 ft.	
*Storage Temperature:	$-65^{\circ}F$ to $+160^{\circ}F$	
*Shipping Temperature:	$+20^{\circ}F$ to $+120^{\circ}F$ - The shipping container must be marked to reflect the temperature control.	
*Humidity:	0 to 100 percent relative humidity including condensation.	
*Rain:	Rain as defined in Method 506 - MIL-STD-810(USAF) 14 June 1962.	
*Salt Spray:	Salt Spray as encountered in a beach area (equivalent to spray of 5% salt solution in water for 50 hours).	
*Sand and Dust:	As in desert and ocean/beach areas, equivalent to 140 mesh silica flour with particle velocity up to 500 ft/min.	
Fungus:	In accordance with Method 508, MIL-STD-810(USAF) 14 June 1962.	
*Ozone:	Exposure with 0.05 parts/million concentration (1/2 toxic limit).	

*Ambient environment on outside of Package.

TABLE I (Continued)

(b) Prelaunch Unpackaged (Tanks Empty and Slightly Pressurized)

Acceleration: (ns)	2.67g vertical with 1.0g lateral
Shock: (ns)	Shock as in MIL-STD-810(USAF) 14 June 1962, Method 516, Procedure I, Modified. Modify shockpulse to saw tooth 15g peak 10-12 ms rise, 0-2 ms decay.
Vibration: (ns)	Same as prelaunch packaged but applied to equipment.
External Pressure:	Ambient at sea level.
Internal Tank Proof Pressure:	333 psig.
Temperature:	+20°F to +110°F Ambient Air Temperature with a superimposed solar radiation intensity of 360 BTU/ft^2 hr up to 6 hr/day.
Humidity:	15% to 100% relative humidity including condensation.
Rain:	Same as packaged but no direct impingement.
Salt Fog:	As in MIL-STD-810(USAF) Method 509.
Sand and Dust:	Same as prelaunch packaged.
Fungus:	Same as prelaunch packaged.
Ozone:	Same as prelaunch packaged.

(ns) These levels of environments and loads do not occur simultaneously.

TABLE I (Continued)

(c) Launch and Boost (Tanks Full)

Accelerations and Tank Pressures:

Condition / Loading	Boost (ns)		Burnout (ns)		Engine Hardover (ns)	

External Pressure: Ambient at Sea Level to 1 x 10^{-10} mm Hg.

Internal (psia) Pressure		22	130	22	130	22	130
Nx	See Tank Assy. Drawing LSC310-405	5.65g	5.65g	-1.4g	-1.4g	2.4g	2.4g
Ny		0	0	0	0	± .7g	± .7g
Nz		0	0	0	0	0	0

External Pressure: Ambient at sea level to 1 x 10^{-10} mm Hg

Internal Tank Pressure: (s) 22 to 130 psia.

Vibration: The randon spectrum shall be applied for 17 minutes along each of three mutually perpendicular axes, x, y and z.

5-27 cps	.18g^2/cps constant
27-40 cps	12 db/octave rolloff to
40-2000 cps	.036g^2/cps constant

(ns) The levels of this environment do not occur simultaneously with the vibration environment.

(s) Simultaneously with random vibrations.

TABLE I (Continued)

(c) Launch and Boost (Continued)

Temperature: +40 to +100°F within the propulsion compartment. 0 to +110°F ambient at sea level.

Acoustics:

Octave Band (cps)	Level (db)
9 to 18.8	142
18.8 to 37.5	141
37.5 to 75	141
75 to 150	138
150 to 300	134
300 to 600	130
600 to 1200	123
1200 to 2400	116
2400 to 4800	110
4800 to 9600	104
Overall	147

Humidity: Same as prelaunch packaged.

Hazardous Gases: Explosive-proofing requirement defined in Method 511, MIL-STD-810, 14 June 1962.

Radiation: See paragraph 3.4.1.

TABLE I (Continued)

(d) Space Flight - Translunar (Tanks Full)

Accelerations and Tank Pressures:

Condition / Loading	Service Module Propulsion Sys. Operating		Not Operating		Transpositioning Not Operating	
Internal Pressure (psia)	22	130	22	130	22	130
Nx (See Tank Assy. Dwg. LSC310-405)	-.45g	-.45g	0	0	-.84g	-.84g
Ny (See Tank Assy. Dwg. LSC310-405)	$\pm$ .11g	$\pm$ .11g	0	0	-	-
Nz (See Tank Assy. Dwg. LSC310-405)	0	0	0	0	-	-
Axis normal to x	-	-	-	-	.12g	.12g
Angular (rad/sec^2)	-	-	-	-	17.0	17.0

Vibration: Service Module Propulsion operating — The mission environment consists of the following random spectrum applied for 6 minutes along each of the three mutually perpendicular axes, x, y and z.

5-47 cps	.089g^2/cps constant
47-65 cps	12 db/octave rolloff to
65-1000 cps	.024g^2/cps constant
1000-2000 cps	12 db/octave rolloff

Internal Pressure: 22 to 130 psi

External Pressure: 1 x 10^{-14} mm Hg uncontrolled vacuum

Temperature: +40° to 100°F in propulsion comp.

Radiation: Van Allen, Solar Flare & Space background. To be defined as needed (inner belt 10 min. 1/2 hr. delay - outer belt. See paragraph 3.4.1).

TABLE I (Continued)

E. Lunar Descent (Tanks Full)

Accelerations and Tank Pressures:

Condition / Loading	Descent Engine Operating		Transfer Orbit		(preliminary) Landing Cond. a		(preliminary) Landing Cond. b	
External Pressure: 1×10^{-10} mm Hg								
Internal Pressure (psia)	177	250	177	250	177	250	177	250
Nx (See Tank Dwg. LSC-310-405)	+1.10g	+1.10g	0	0	+8.0g	+8.0g	+7.0g	+7.0g
Ny	-	-	0	0	0	0	±4.0g	±4.0g
Nz	-	-	0	0	0	0	±5.0g	±5.0g
Axis normal to x — linear	.16g	.16g	-	-	-	-	-	-
Axis normal to x — angular (rad/sec.^{2})	.667	.667	-	-	-	-	-	-
x — angular (rad/sec.^{2})	-	-	-	-	-	-	± 5	± 5
y	-	-	-	-	-	-	±10	±10
z	-	-	-	-	-	-	±10	±10

Shock: (preliminary) 8g any axis (10-20 milliseconds duration)

Vibration:

Descent Engine Operating

The mission environment consists of the following random spectrum applied for 11-1/2 minutes along each of the three mutually perpendicular axes, x, y and z.

10-28 cps	.18g^2/cps constant
28-37 cps	12 db/octave rolloff to
37-1000 cps	.059g^2/cps constant
1000-1200 cps	12 db/octave rolloff to
1200-2000 cps	.031g^2/cps constant

External Pressure: 1×10^{-10} mm Hg uncontrolled vacuum

Internal Pressure: 177 to 250 psia.

Temperature: 40°F to 100°F propulsion compartment.

Radiation: See paragraph 3.4.1.

TABLE I (Continued)

(f) Lunar Stay (Tanks Full or Empty)

Acceleration:	1/6g in x direction (at rest)
External Pressure:	1×10^{-10} mm Hg uncontrolled vacuum
Internal Pressure:	177 to 250 psia
Temperature:	40° to 100°F propulsion compartment
Radiation:	See paragraph 3.4.1

TABLE I (Continued)

(g) Lunar Ascent (Tanks Full or Empty)

Accelerations and Tank Pressures

Loading \ Condition	Ascent Engine Operating Maneuver		Docking		Transfer Orbit	
Internal Pressure (psia)	0	250	0	250	0	250
Nx	1.2g	1.2g	0	0	0	0
Ny (Nx, Ny, Nz: See Tank Assy Dwg LSC310-405)	.06g	.06g	0	0	0	0
Nz	0	0	-4.0g	-4.0g	0	0

External Pressure: 1×10^{-10} mm Hg uncontrolled vacuum.

Vibration:

Ascent Engine Operating

The mission environment consists of the following random spectrum applied for 8-1/2 minutes along each of the three mutually perpendicular axes, x, y and z.

10-28 cps	$.18g^2$/cps constant
28-37 cps	12 db/octave rolloff to
37-1000 cps	$.059g^2$/cps constant
1000-1200 cps	12 db/octave rolloff to
1200-2000 cps	$.031g^2$/cps constant

Temperature: 40° to 100°F in propulsion compartment.

Radiation: See paragraph 3.4.1.

TABLE II

QUALIFICATION TESTS

Name of Test	Paragraph	Remarks
Inspection Before Tests	4.4.2.2.1	
Operational	4.4.2.2.2.1	
Leakage	4.4.2.2.2.2	
Proof Pressure	4.4.2.2.2.3	
Burst Pressure	4.4.2.2.2.4	
Fluid Compatibility	"No Test"	BAC Certification required
Volume Verification	4.4.2.2.2.6	
Slosh	4.4.2.2.2.7	
Extreme Temperature	4.4.2.2.2.8	
Shock	4.4.2.2.2.9	
Acceleration	4.4.2.2.2.10	
Vibration	4.4.2.2.2.11	
Endurance Cycling	4.4.2.2.2.12	
Weight	4.4.2.2.2.14	
Post-Test Inspection	4.4.2.2.3	

NOTE: A specific test sequence is not implied in the above list.

TABLE III

ACCEPTANCE TESTS

Name of Test	Paragraph	Remarks
Inspection Before Tests	4.4.3.2.1	
Weight	4.4.3.2.2.1	
Operational	4.4.3.2.2.2	
External Helium Leakage	4.4.3.2.2.3	
External Propellant Leakage	4.4.3.2.2.3	
Proof Pressure	4.4.3.2.2.4	
Vibration	4.4.3.2.2.5	See Below
Rinse	4.4.3.2.2.6	

Acceptance Test Levels

Vibration:

Random

Intensity	Cycles	Remarks
Constant $0.35g^2/cps$	20-90 cps	Random vibration shall be 5 minutes for each mutually perpendicular axis for a total time of 15 minutes.
12 db/octave rise (approx.)	90-100 cps	
Constant $0.059g^2/cps$	100-1000 cps	
12 db/octave rolloff (approx.)	1000-1100 cps	
Constant $0.035g^2/cps$	1100-2000 cps	

TABLE IV

REQUIREMENTS FOR QUALIFICATION TESTS

Test Description	Intensity or Rate	Cycles or Time	Remarks
Temperature	-65°F +160°F	Exposure for 12 hours at each.	Equipment shall survive this non operating per 4.4.2.2.2.8.
Acceleration Cond. Boost	X +8.5g	Exposure for 5 minutes per direction for a total of 10 minutes.	Tanks fully loaded, pressure of 195 psig in the ± X direction.
Vibration Random:	$.08g^2$/cps 12 db/octave rise $0.133g^2$/cps 12 db/octave fall $.08g^2$/cps	from 20 to 88 cps from 88 to 100 cps from 100 to 1000 cps from 1000 to 1150 cps from 1150 to 2000 cps	See Note 3.
Sinusoidal:	0.23 inch DA 2.9g .007 inch DA 6.9g .001 inch DA 12.5g	from 5 to 16 cps from 16 to 90 cps from 90 to 140 cps from 140 to 360 cps from 360 to 500 cps from 500 to 2000 cps	See Note 4.
Shock (Preliminary)	12g	10-20 milliseconds duration with a saw tooth shape.	Shock shall be applied three times in both directions along three mutually perpendicular axes for a total of 18 shocks.

NOTES: 1. Tanks shall be pressurized to 250 psig during random and sinusoidal tests and tanks shall be full.

2. Simulated test propellants are to be used.

TABLE IV (Continued)

NOTES: (Continued)

3. Random Vibration Tests shall be 30 minutes for each of the three mutually perpendicular axes for a total time of 90 minutes.

4. Sinusoidal Vibration frequency shall be swept logarithmically from 5 to 100 cps and back at 1/3 octave per minute for one cycle for each orthogonal axis and shall be swept logarithmically from 100 to 2000 cps and back at one (1) octave per minute for one cycle for each orthogonal axis.

5. The sinusoidal and random conditions shall be imposed sequentially.

6. Tanks are pressurized to 250 psig and 3/4 full during shock test.

TABLE V

WEIGHTS

Oxidizer Tank Shell Subassembly		
Oxidizer Positive Expulsion Device	___	
Oxidizer Tank Assembly (Total)	12.58	lbs.
Fuel Tank Shell Subassembly		
Fuel Positive Expulsion Device	___	
Fuel Tank Assembly (Total)	10.50	lbs.

The above weights are for one (1) oxidizer and one (1) fuel tank assembly. The total weight of two (2) oxidizer tank assemblies and two (2) fuel tank assemblies shall not exceed 46.16 lbs.

TABLE VI

CONTAMINATION LEVELS

Particle Size Range in Microns	0-5	5-10	10-25	25-50	50-75	75-100	Over 100
Max. No. of Particles per 100 ML Rinse Test Fluid	Unlimited	Unlimited	Unlimited	1960	110	12	0

1. One micron is equal to 1 x 10^{-6} meters or 0.00003937 inch.

2. Contaminates are categorized as either particle or hydrocarbon. Particle contamination is considered to include any discrete solid particles, metallic or non-metallic, small enough to be detrimental to the components of the particular system being considered. The size of the particle shall be determined by its largest dimensions. The term hydrocarbon or organic contamination is less exact. It is intended to define those contaminates which are not compatible with the fluid media. All hydrocarbon contamination that is soluable in Freon TF cleaning agent will be removed from the tanks. Hydrocarbon contaminates are known as non-volatile residues.

TABLE VII

QUALITY ASSURANCE TESTS FOR

FORGINGS AND FORGING MATERIALS

Types of Tests	Billets		Forgings
CHEMICAL ANALYSIS			
General chemistry	Mid Radii top and botton	100%	N
Residual gas analysis	Mid Radii top and botton	100%	S
MACRO EXAMINATIONS			
Chemical segregations	top and bottom macroslabs	100%	N
Grain flow		N	1st piece (a)
MICRO EXAMINATIONS			
Beta transus determination	Mid Radii top and bottom	S	N
Grain size determination		N	S (b)
General structure	Mid Radii top and bottom	S	S (b)
HEAT TREAT RESPONSE			
Tensile tests (a) and (c) 0.252 inch diameter bar to include; ultimate tensile strength, yield strength, (0.2% offset), yield strength (0.02% offset), reduction of area, and elongation.		N	100%
RADIOGRAPHIC INSPECTION (d)		N	100%
ULTRASONIC INSPECTION (e)		N	100%

NOTES: N - Not required or not applicable.

S - Sampling Plan

TABLE VII (Continued)

NOTES: (Continued)

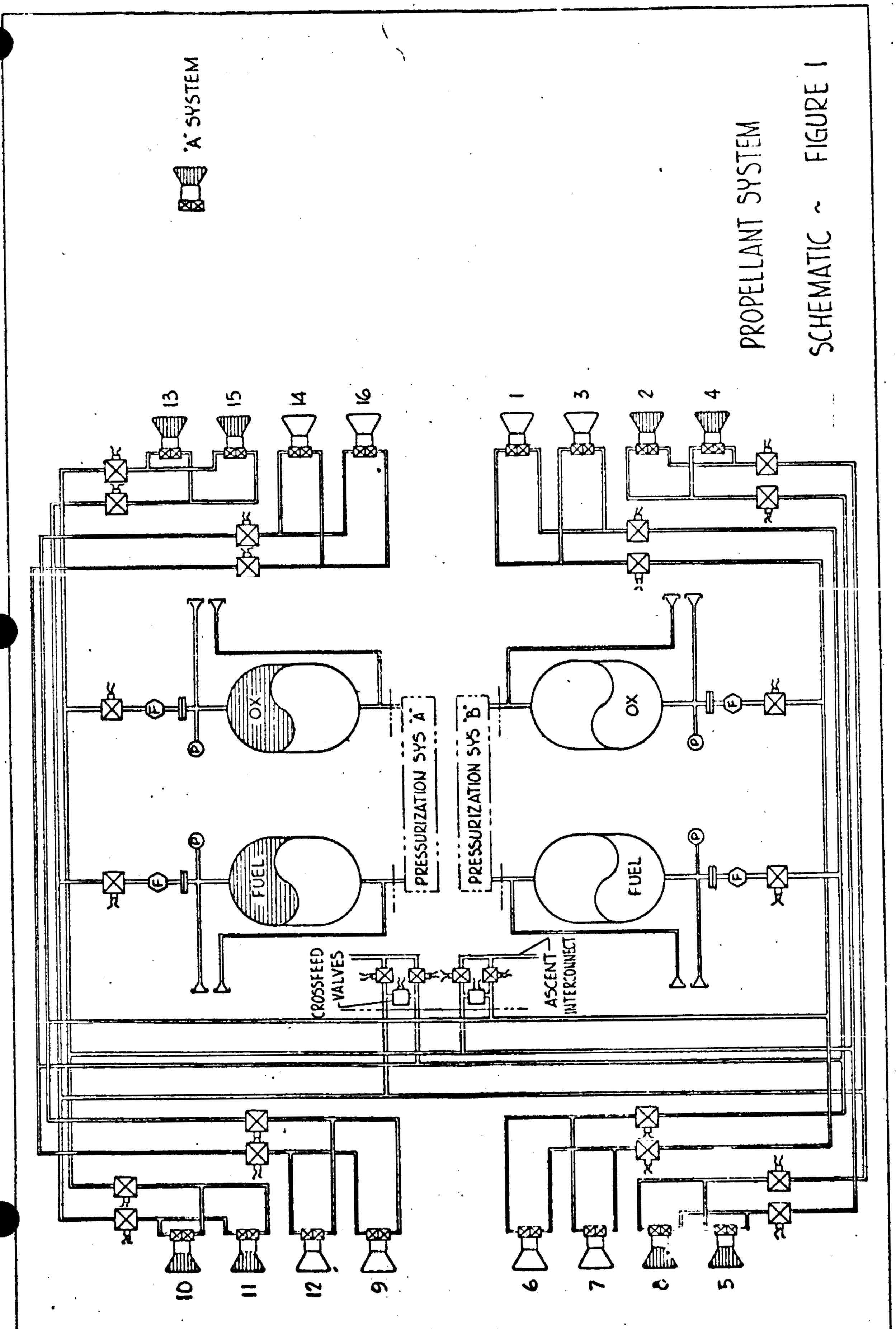
(a) After the forging technique has been established for each type component, one forging shall be destructively tested to determine the grain flow and mechanical properties. If the forging practice is altered, in each case, one additional forging shall be destructively tested.

(b) In the fully aged condition there shall be no evidence that the forging temperature or solution treating temperature exceeded the beta transus. The microstructure shall be equiaxed primary alpha or plate-like alpha in a transformed beta matrix. Acicular alpha or alpha outlining prior beta grains shall be evidence of overheating and cause for rejection. Equiaxed primary alpha particle size shall be predominately ASTM-8 or finer as determined by ASTM-E-112.

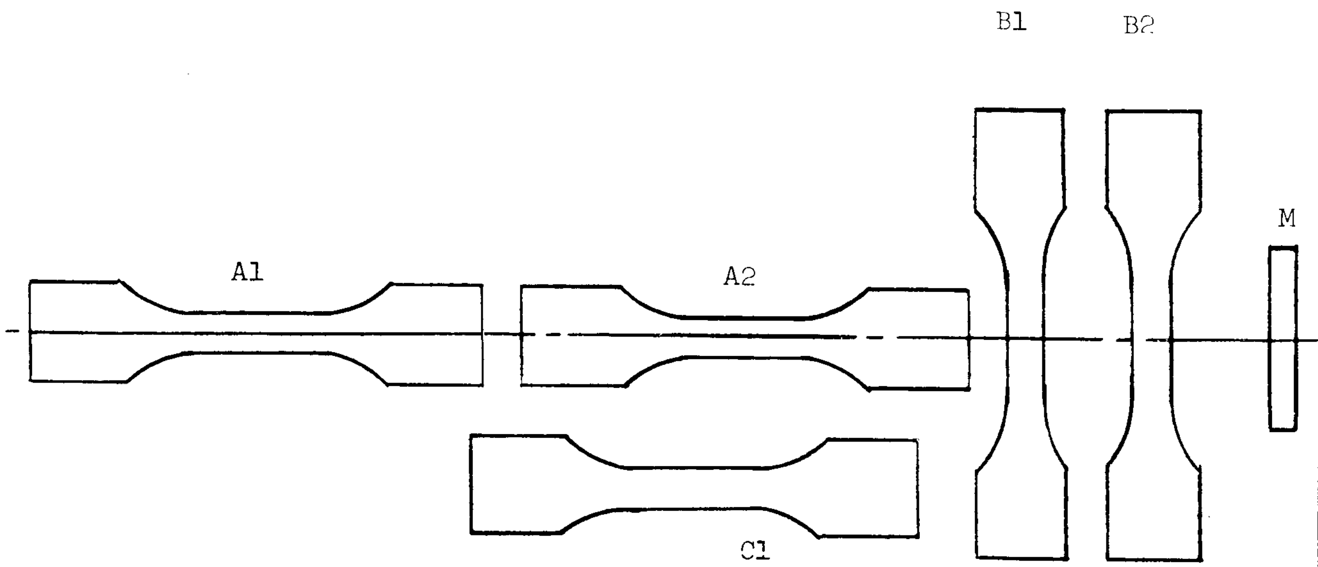
(c) Test specimens shall be processed in accordance with 4.4.1.1.9 and meet the requirements of 3.8.6.3.

(d) Radiographic inspection per MIL-STD-453 for conformance to paragraph 3.1.1.1. High density particles or voids are not acceptable in the finish machined component.

(e) Ultrasonic inspection to Class A requirements for conformance to paragraph 3.1.1.1, i.e., 5/64 inch maximum indication with 3/64 inch maximum indication on one inch centers. Finish machined components shall have no ultrasonic indications.



PROPELLANT SYSTEM
SCHEMATIC ~ FIGURE 1



DENOTATION:

A - Longitudinal Weld

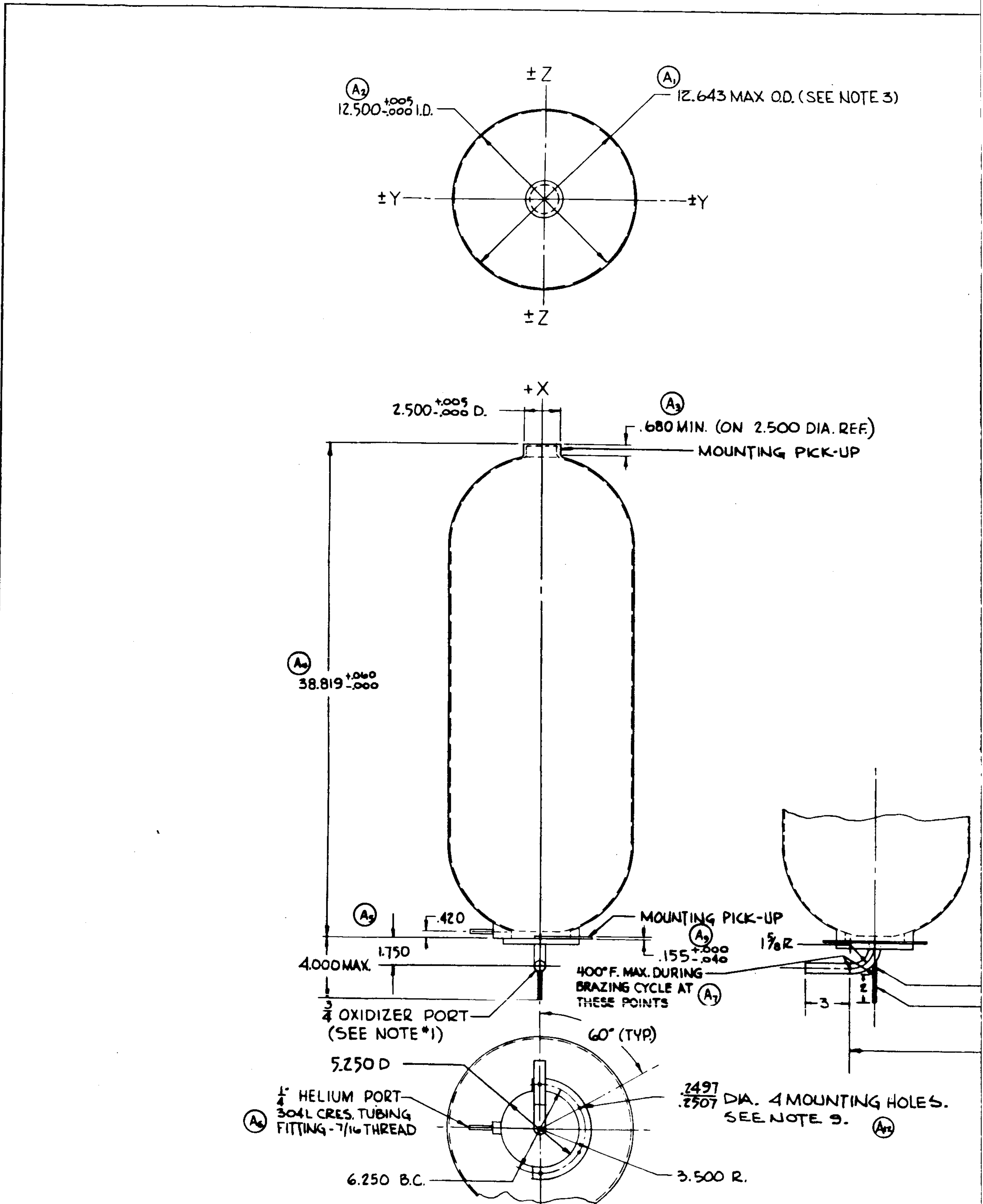
B - Transverse Weld

C - Parent Metal

M - Microscopic Specimen

FIGURE 2

WELDMENT TESTBAND COUPON WITH METALLURGICAL TEST SPECIMENS


±Z
A2
12.500 +.005 -.000 I.D.
A1
12.643 MAX O.D. (SEE NOTE 3)
±Y
±Y
±Z
+X
2.500 +.005 -.000 D.
A3
.680 MIN. (ON 2.500 DIA. REF.)
MOUNTING PICK-UP
A4
38.819 +.060 -.000
A5
.420
MOUNTING PICK-UP
A9
.155 +.000 -.040
1.750
4.000 MAX.
400°F. MAX. DURING BRAZING CYCLE AT THESE POINTS
A7
1 5/8 R
3
2
3/4 OXIDIZER PORT (SEE NOTE #1)
60° (TYP.)
5.250 D
1/4" HELIUM PORT 304L CRES. TUBING FITTING-7/16 THREAD
A6
.2497 / .2507 DIA. 4 MOUNTING HOLES. SEE NOTE 9.
A12
6.250 B.C.
3.500 R.

CHANGE LETTER	CHANGE NO.	DESCRIPTION OF CHANGE AND REASON	CHANGE BY AND DATE	ENGRG APPD	NASA APPD
A	1	ADDED 12.643 MAX. O.D. FOR -1 ASSY. & 12.633 MAX. O.D. FOR -2 ASSY.	L.R.B. 12-18-63	[illegible]	
	2	ADDED 12.500 $\pm$[illegible] I.D.		[illegible]	
	3	.680 MIN. WAS .812 MIN. (ON 2.500 DIA. REF.) FOR MOUNTING PICK-UP		[illegible]	
	4	ADDED 38.819 DIM. FOR -1 ASSY. AND 32.209 DIM. FOR -2 ASSY.		[illegible]	
	5	REVISED LOCATING DIMS. FOR 3/4" PORTS		[illegible]	
	6	ADDED MAT'L. CALLOUT FOR 1/4" HELIUM PORT		[illegible]	
	7	ADDED BRAZING INFO.		[illegible]	
	8	ADDED MAT'L. FOR HELIUM & OXIDIZER PORTS			
	9	MOUNTING PICK-UP THICKNESS .155 $\pm$[illegible] WAS .125			
	10	REVISED NOTES 3, 6 & 8.			
	11	REMOVED NOTES FROM SHEET 2			
	12	ADDED NOTE 9. .2497-.2507 WAS .257			

NOTES:

1. TENTATIVE PORT REQ'MTS NOTED. CONFIGURATION OF PORTS SHALL BE SPECIFIED AT A LATER DATE.
2. TANKS SHALL BE MOUNTED AT EACH END.
3. (A10) THIS DIAMETER IS A MAXIMUM AT THE WELD BEAD.
4. THE DIMENSIONS SHOWN ESTABLISH MAXIMUM ENVELOPE REQUIREMENTS.
5. THE ACTUAL CENTER OF GRAVITY LOCATION SHALL BE NOTED WHEN ESTABLISHED.
6. (A10) ALL DIMENSIONS GIVEN TO 3 PLACES WILL HAVE ±.010 TOLERANCE.
7. SURFACE ROUGHNESS OF ALL INTERIOR AND EXTERIOR SURFACES SHALL BE 63 R.M.S. MAX.
8. (A10) ANY CONNECTIONS THAT MAY BE FASTENED TO THE TANK FUEL, HELIUM OR VENT LINES WILL BE REMOVED AT GRUMMAN.
9. (A12) MOUNTING HOLES ARE TO BE LOCATED & DRILLED FROM GRUMMAN SUPPLIED MASTER TOOL.

— 3/16 O.D. AL ALLOY VENT

— BI-BRAZE, 2 IN 3/16 O.D. x .016 WALL 304L CRES. TUBING. (A8)

— BI-BRAZE, 3 IN 3/4 O.D. x .016 WALL 304L CRES. TUBING. (A8)

LSC 310-405-1
TANK ASSY, OXIDIZER

SPECIFICATION CONTROL DRAWING
THIS DRAWING FORMS A PART OF
LSP-310-405A CONTROL SPEC.

DEPT	CODE	SIGNATURE
DRAWN	310	E.L. KLEIN
CHECKED	310	[illegible]
SUBSYSTEM	310	[illegible]
STRUCTURES	520	[illegible]
WEIGHTS	490	[illegible]
VEH DES & INT	280	[illegible]
SYSTEM CORD	520	[illegible]
SPECIF	14	[illegible]
SS PROJ ENGR	260	[illegible]
Reliability	550	[illegible]

GRUMMAN AIRCRAFT ENGRG CORP
BETHPAGE, L. I., N. Y.

TANK, PROPELLANT
POSITIVE EXPULSION, R.C.S.

CONTRACT NO. NAS 9-1100

CODE IDENT NO.	SIZE		
26512	D 22-34	LSC 310-405	A
SCALE 1/4 : 1	WEIGHT		SHEET 1 OF 2